UNITED STATES DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU PACIFIC REGION
P. O. Box 3650
Honolulu, Hawaii 96811

January 13, 1966

MEMORANDUM WFP/M

TO: All First Order Stations, Pacific Region

FROM: Regional Meteorologist, Pacific Region

SUBJECT: Technical Memorandum #1

The attached paper is a description and study of local wind effects at one of our stations. Maui is typical of the mountainous type of island, many of which are found in the tropical Pacific. It is hoped that the publication of this paper will encourage all of you to submit similar ideas for publication. This is especially important in view of the present emphasis on development of local forecasting techniques.

	INFO	ACTION
RD		
RGUS		
RC		
RH		
RM		
TEQI		
RADR		
OPNS		
WXAP		
A&FW		
ASOM		
DATC		
COMM		
OBSN		
SM		
ADTC		
ENGR		
FAC		
ELEC		
ADMN		
SDGT		
FISC		
PERS		
P&S		
M&F		

Papers submitted may be published locally in one of two series. One series will be a subseries of the Weather Bureau Technical Notes and will be entitled, "Pacific Region Technical Note No. ____". Papers published in this subseries will be selected by the regional headquarters but edited and published by the Central Office. Normally papers published in this series will be research and development studies pertaining to the Pacific. The second series will be entitled, "Pacific Region Technical Memorandum No. ____". This series will be edited and published by the regional headquarters. In general papers published in this series will be of technical material pertaining more to operations or of directive nature. The attached paper is one of this latter series.

Edward M. Carlstead
Edward M. Carlstead

Attachment

cc: Dr. Klein, Techniques Dev. Lab., SDO
Reg Mets, Other Regions
Central Region

UNITED STATES DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU PACIFIC REGION

TECHNICAL MEMORANDUM NO. 1

The Trade Wind Regime of Central and Western Maui

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Honolulu, Hawaii

Scientific Services Division
January 1966

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ACKNOWLEDGMENTS

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THE TRADE WIND REGIME OF CENTRAL AND WESTERN MAUI

C. M. Peterson

1. Introduction

The island of Maui, second largest of the Hawaiian Islands, is noted for its varied orographic features. The massive 10,000 foot high Mt. Haleakala dominates the island landscape and forms an immense barrier to normal air flow, and the lower but deeply eroded west Maui mountains form a secondary barrier. Maui's central valley between these two mountain masses is open to the persistent tradewinds that blow from the northeast. These features present, indeed, unique problems to the forecaster.

Available records, personal observations, and interviews with reliable residents over a period of three years have led to this presentation of general tradewind patterns in the central valley and along the leeward slopes of the west Maui mountains. This discussion has been confined to tradewind situations since they prevail during every month of the year and occur approximately 65% of the time.

2. Surface Circulation in the Central Valley

Average tradewind direction at the Kahului airport at the northern end of the valley is 55° (TABLE I). Progressing southward through the valley, the "Trades" are deflected toward a more northerly direction by the north-south alignment of the west Maui mountains and, at the Puunene Naval Air Station site 5 miles south-southwest of Kahului airport and near the center of the valley, average direction is 23°.

The range of surface tradewind direction which accounts for 80% of the monthly prevailing and 51% of all hourly occurrences is 50 to 70 degrees. Throughout this direction range, air arrives at the Kahului airport with an overland trajectory of no more than 1.6 miles, all of which is upslope directly from the sea to the wind instrument exposure site at an elevation of 69 feet. Deflection off the north slope of Haleakala causes a converging of the streamlines and resulting higher wind speeds near the Kahului airport at the entrance to the central valley. Further acceleration results downwind as the inertia of this moving air current carries it against the west Maui mountains causing an even more pronounced packing of the streamlines along the western edge of the valley. Daytime speeds 2 miles west of Puunene often exceed an estimated 35 mph.

TABLE I

	Kahului Airport, 40° to 80° inclusive. 6 year record.	Puunene NAS 350° to 30°. 32 month record
Occurrences, monthly prevailing	68	28
Average direction	55°	23°
% of time prevailing	94	87
% of hourly occurrences	58	71
Average speed, mph	*12.1	12.5

(* 1 year record. Five year average at prior exposure height of 72 feet above ground was 17.5 mph.)

The "Trades" remain generally confined to the western half of the valley as they approach its south end and leave an area of relative calm or light eddy motions to the lee of Haleakala. Near noon, under average conditions of cloudiness, the sea-breeze component is introduced and causes still further acceleration of the "Trades" through the northern portions of the valley and a turning of this narrow band back into the partial void to the lee of Haleakala after a short trajectory over the waters of Maalaea Bay at the south end of the valley. The "Trades" along the western shore of Haleakala and the southeastern central valley thus arise abruptly and come from a northwesterly direction. This current then begins to diverge with the inner portion continuing to curve cyclonically into the eastern central valley and the lower lee slopes of Haleakala as a gentle southerly sea-breeze, and the outer curving anticyclonically to merge with the prevailing "Trades" to the southwest of Haleakala. Leopold[1] has discussed the interaction of the northerly "Trades" of the western central valley and these returning sea-breezes.

3. Upper Winds and Their Relationship to Surface Tradewinds in the Central Valley.

When winds aloft 5,000 to 10,000 feet are northeasterly and average 15 knots or more through the layer, surface wind across the northwestern two thirds of the Kahului airport and along the western portion of the valley will remain northeasterly 10 mph or greater throughout the night (TABLE II) while the northwesterly on-shore winds in the southeastern central valley will subside as the land-sea breeze component reverses.

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[1] Luna B. Leopold, "The Interaction of Trade Wind and Sea Breeze, Hawaii." Journal of Meteorology, Oct. 1949, Vol. 6, p. 316.

With northeast winds aloft 5,000 to 10,000 feet averaging less than 15 knots, surface wind at the Kahului airport will diminish to light and variable during the night, a northeast sea-breeze will arise there at 7 to 10 a.m. and subside at 6 to 10 p.m. depending on the season, and the on-shore afternoon westerly winds of the southeastern central valley will occur only in occasional gusts with conditions generally light and variable.

As used in Tables II and IV, "critical" winds are defined as follows:

Aloft - Northeasterly and averaging 15 knots or more 5,000 to 10,000 feet.

Surface - Northeasterly 20 mph daily average 1/1/62 through 10/18/63, northeasterly 15 mph following above dates. Wind instrument exposure lowered from 72 feet to 21 feet 10/19/63.

TABLE II

Month	A %	B %	C %
Jan	81	100	90
Feb	100	80	100
Mar	100	80	33
Apr	100	81	72
May	97	81	74
Jun	91	87	79
Jul	76	85	76
Aug	97	84	68
Sep	85	89	78
Oct	85	93	93
Nov	87	100	91
Dec	100	75	60
Year	92	86	76

Column A - Days with "critical" wind aloft on which minimum night-time surface speed was 10 mph or more. 204 occurrences.

Column B - Days with less than "critical" wind aloft on which night-time surface speed was less than 10 mph. 504 occurrences.

Column C - Days with "critical" wind aloft on which daily average surface speed also qualified as "critical."

Further examination of the upper wind observations taken at Kahului reveal the following interesting facts:

a. Under a tradewind regime, the surface to 3,000 foot wind is markedly accelerated and deflected by local conditions.

b. 5,000 feet appears to be the lowest level at which a true gradient wind prevails. This is also the lowest level at which no appreciable downwind obstruction exists.

c. The 15 knot average speed must prevail throughout the 5,000 to 10,000 foot strata to produce "critical" surface wind; a lower or shallower strata will not have this effect.

d. The average direction at 5,000 feet when "critical" conditions prevail is 77°.

4. The Surface Circulation of Western Maui.

The alignment of the west Maui mountains and the presence of several major gulches through the range are the primary reasons for the complex surface wind circulation in western Maui.

Two years of record at Wahikuli (TABLE III), 5 miles directly downwind from Puu Kukui (5788) reveals the existence of a combination land-sea and mountain-valley breeze circulation in that area. Of 672 days of record studied, on only 125 days was there a significant departure from a land-sea breeze circulation and on only 63 days was this a tradewind; while in unobstructed areas nearby, tradewinds occur 65% of the time.

TABLE III

ANNUAL WIND ROSE - WAHIKULI

Direction	N	NE	E	SE	S	SW	W	NW	CALM	ALL
Occurrences %	6	12	39	4	15	13	10	1-	1-	100
Avg. Speed	7.0	6.5	4.4	4.8	6.8	6.4	5.4	4.6	0.0	5.8

The temporary installation of several wind recorders along the western slope by Pioneer Mill Co. during the latter half of 1963 provided the opportunity to establish the basic flow patterns of that area. (FIGURE III). It was determined that the northern portion of the leeward slope experiences a predominant tradewind flow with its southern extremity oscillating between lines drawn tangent to the 3,000 foot contour on the north end of the mountain chain and bearing 50° and 70°, this being the direction range

within which approximately 78% of all tradewind occurrences fall. A highly persistent land-sea breeze circulation prevails near the center of the western slope in a triangular shaped area downwind of Puu Kukui, the points being located at the north and south tips of the 3,000 foot contour and the apex approximately 2 miles offshore west of Lahaina. The exits of two deep gulches near the south end of this mountain range serve as nozzles to direct frequent strong northerly gusts across the narrow coastal plain. (FIGURES I and II).

The Kaanapali resort area lies within the narrow wedge formed by the tradewind limits (50° to 70°), and wind there is characterized by its frequent shifts from tradewind (NE) to sea-breeze (SW). Tradewinds are experienced in the central portion only under extremely unstable conditions and unusually strong northeasterly winds in the 5,000 to 10,000 foot strata. The treacherous winds of the southern portion occur with "critical" upper winds and the simultaneous occurrence of strong tradewinds through the lower 5,000 feet which penetrate the mountain passes at approximately 3,000 feet. The north to northeasterly gusts experienced here often reach estimated speeds in excess of 50 mph and constitute a serious hazard to highway traffic. The turbulence encountered by aircraft in this area ranks with the most severe to be found anywhere in the State.

5. Upper Winds and Their Relationship to Surface Winds in Western Maui.

Here again we find that winds through the 5,000 to 10,000 foot strata hold the key to surface wind behavior (TABLE IV). The strong tradewinds of the central valley ascend the northern end of the eastern slope of the west Maui mountains and are forced to descend the leeward slope by the inertia of the higher level winds; tradewinds over the northern portion of west Maui are strongest with "critical" upper winds. The central portion lies directly downwind from terrain well above 3,000 feet in elevation, and tradewinds in the central valley apparently do not ascend to these heights but are deflected to the south; upper winds, meanwhile, move directly over the summits and leave an area of calm, or light eddy currents, to their lee. The complex terrain features near the southern end of the chain permit the low level tradewinds to penetrate the range through the 3,000 foot passes and interconnected valleys; these currents are then forced to descend through the valleys by the inertia of the "critical" upper winds.

Table IV illustrates the direct correlation of "critical" upper winds to gusty gulch winds (cols. D vs. B) whereas no such relationship is shown between strong low level winds aloft and prevailing gulch winds (cols. C vs. B); high speeds up to and including 5,000 feet are not alone sufficient to produce this phenomena.

TABLE IV

Month 1963	A	B %	C %	D %
July	NE	52	67	67
August	SW	29	121	45
September	NE	47	43	57
October	N	45	93	71

Column A - Monthly surface prevailing direction.

Column B - Northeast occurrences.

Column C - 5000 foot wind 20 knots or more vs. northeast occurrences.

Column D - Upper winds "critical" vs. northeast occurrences.

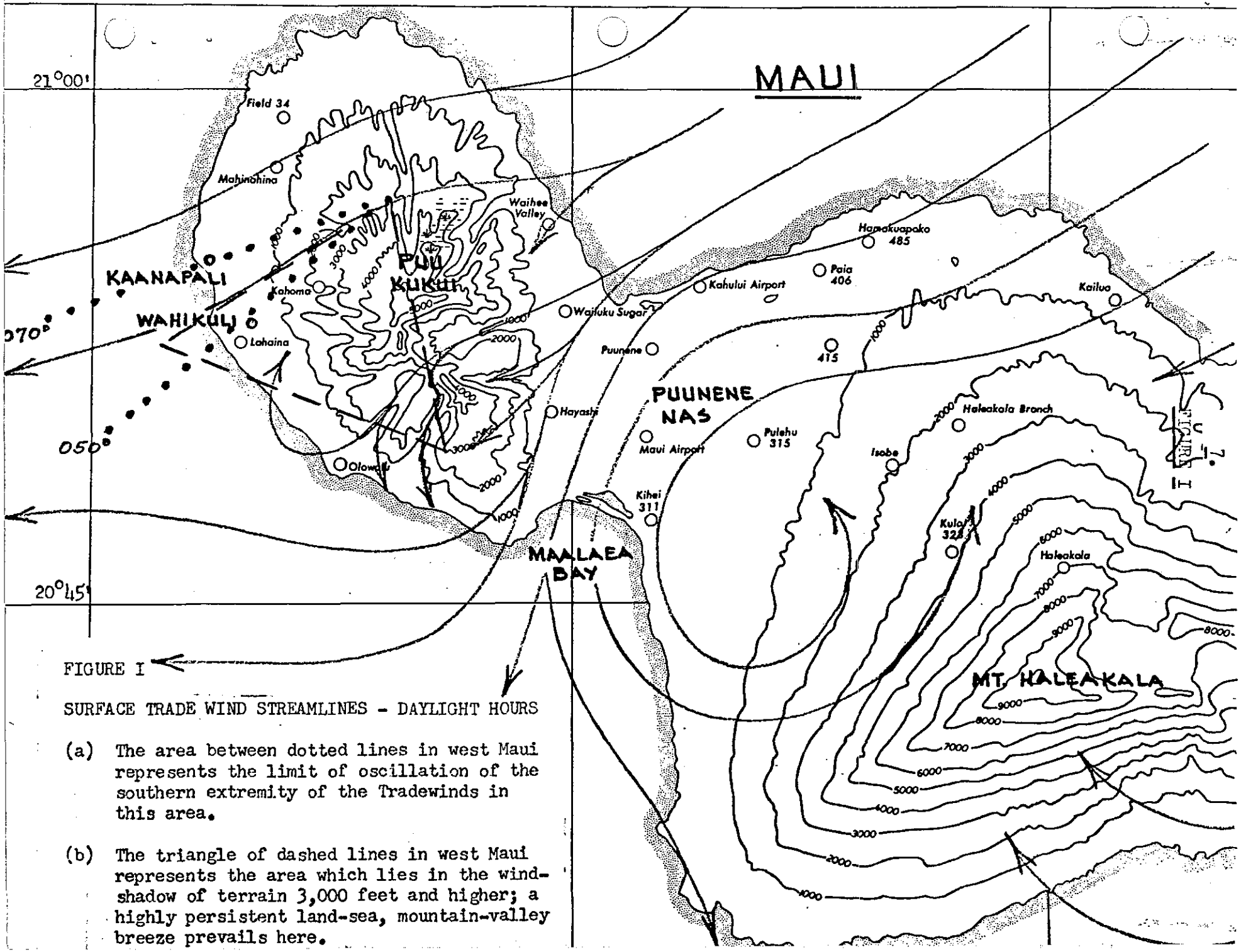

FIGURE I

SURFACE TRADE WIND STREAMLINES - DAYLIGHT HOURS

(a) The area between dotted lines in west Maui represents the limit of oscillation of the southern extremity of the Tradewinds in this area.

(b) The triangle of dashed lines in west Maui represents the area which lies in the wind-shadow of terrain 3,000 feet and higher; a highly persistent land-sea, mountain-valley breeze prevails here.

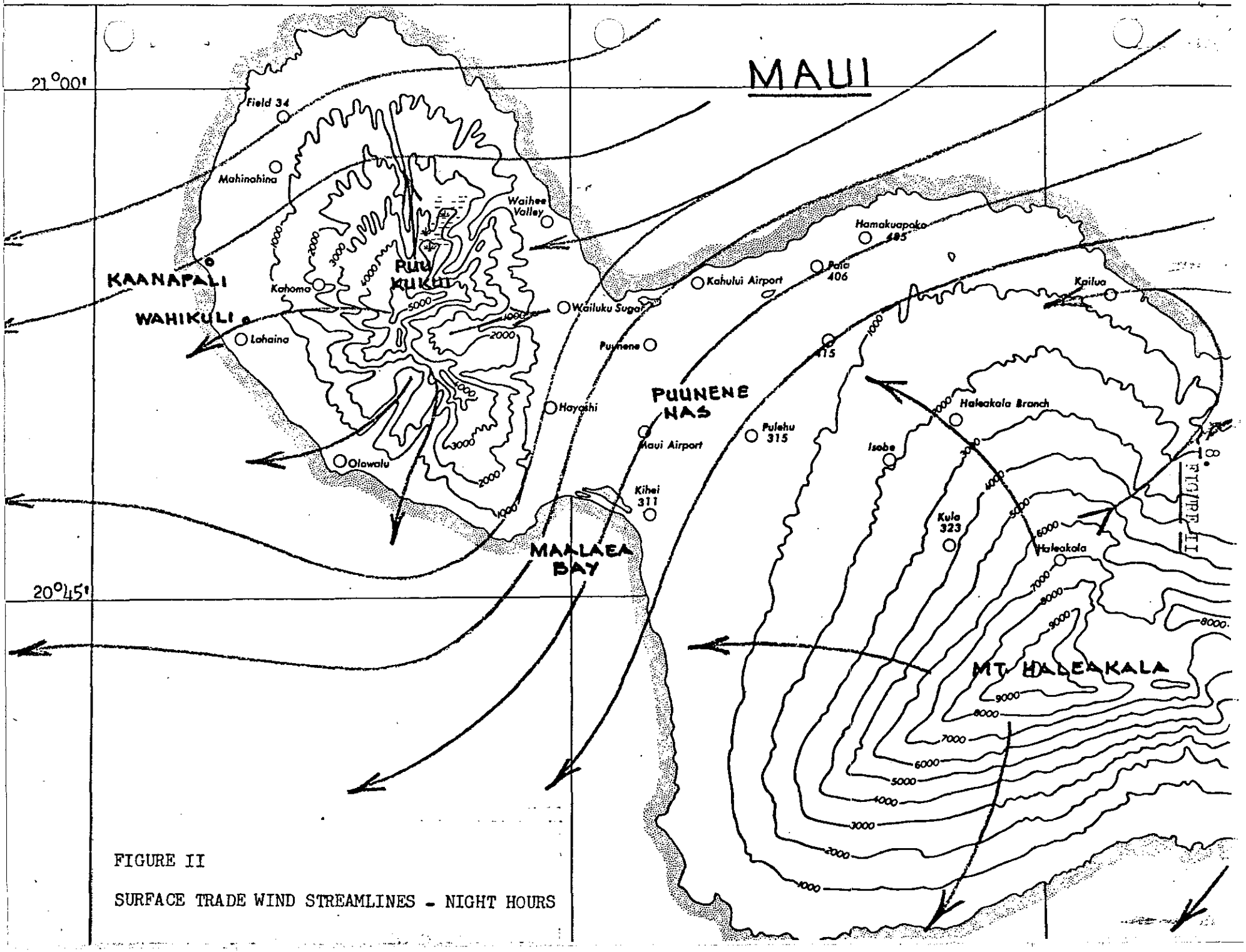

FIGURE II

SURFACE TRADE WIND STREAMLINES - NIGHT HOURS

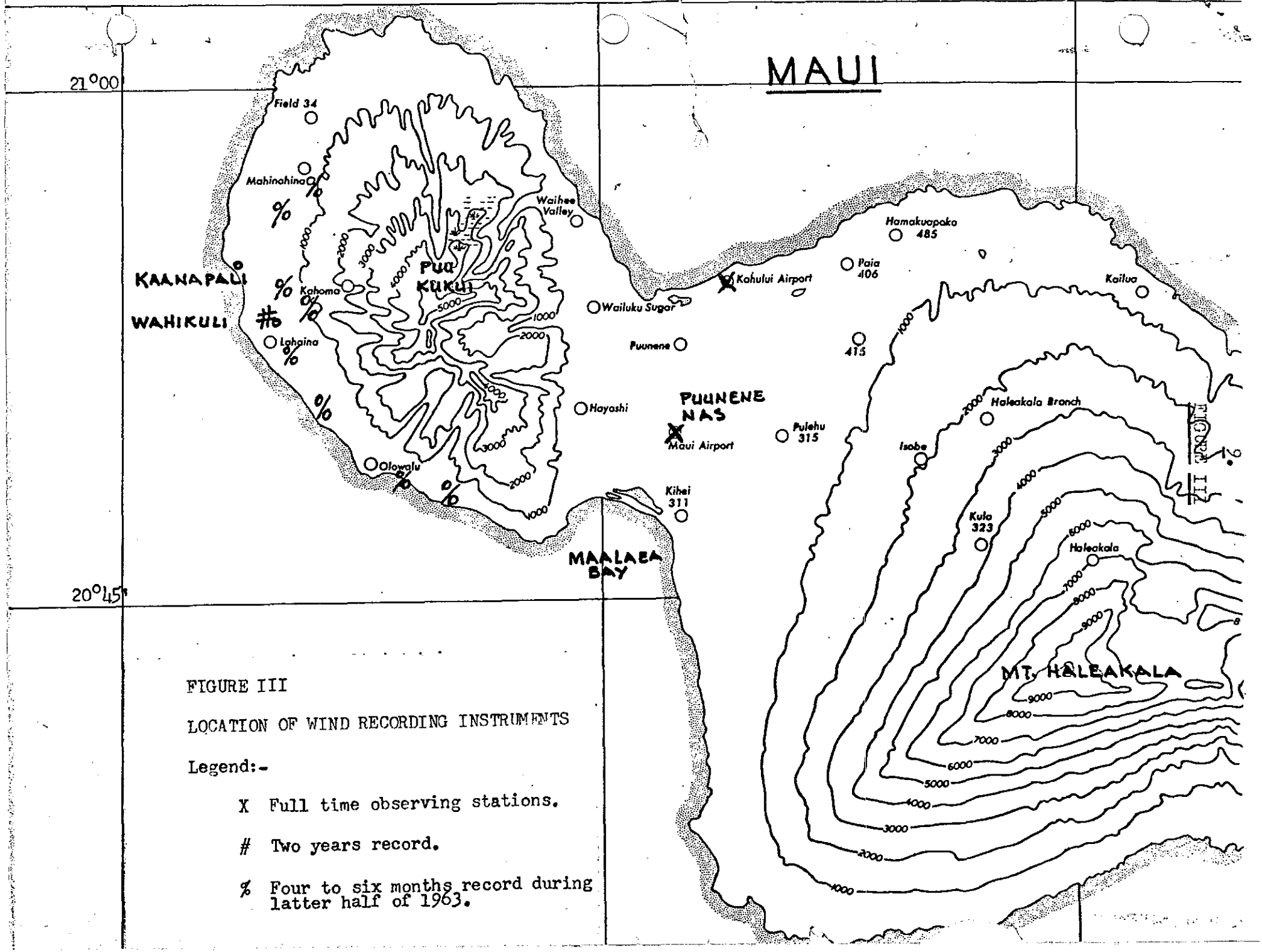

FIGURE III

LOCATION OF WIND RECORDING INSTRUMENTS

Legend:-

X Full time observing stations.

\# Two years record.

% Four to six months record during latter half of 1963.